AIRCRAFT PERFORMANCE CHARACTERISTICS

By

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One of the most obvious consequences of the very rapid progress made in commercial air transport has been the increased capability of the individual to attend meetings in rapid sequence in widely separated locations anywhere in the world. Today, for us to fly from Washington to the West Coast or to Europe is hardly more time consuming or arduous than were journeys 25 years ago from Washington to Boston by surface means.

Tomorrow, we expect to double our speeds. Even then, there is little likelihood we shall be content for long, because assuredly, the scheduling of meetings will have been multiplied at least as rapidly. We can look forward, perhaps with resignation, to the ultimate, an endless round of global conferences, their number limited only by the sitting endurance of those attending!

The urgency with which we seek the new knowledge that will enable us to fly faster and higher and farther is perhaps greater than at any time in the 52 years since Wilbur and Orville first took to the air.

The reason, of course, is not attendance at meetings. Rather, it is because the effectiveness of the airplane as a potent weapon, for use in waging aggressive war or in deterring attack, is dependent on superior performance in speed, altitude, and range.

About a year ago we were asked by the Aviation Facilities Group to predict the probable nature of the commercial air transport inventory in the 1965-1975 time period. After a series of discussions among our senior staff we came up with the following statement:

"The period from now until 1956 will probably be dominated by existing aircraft and by aircraft already in process of design together with their later models. Specifically such airplanes as the Boeing 707, Douglas DC8, Lockheed Electra will come into airline use about 1960 and judging by past experience these aircraft and their later models with more powerful engines and longer fuselages will continue in use throughout the whole period.

"Before 1975 we expect that a prototype supersonic aircraft will make its appearance with a speed of the order of 750 to 800 miles per hour at an altitude of 40,000 feet. We would expect that this airplane would be in about the same position at the end of the period as the jet transport today.

"The role of helicopters, convertiplanes, and vertical takeoff aircraft will be determined mainly by economic considerations. Improved aircraft of these types will be available but it is our feeling that use of these types will be limited to short-haul interurban and to city terminal to large airport and other special purposes during the next 15 or 20 years. At present the vertical takeoff capability is coupled with reduced payload and hence an economic penalty. This situation may change with continued development."

This is as good a prediction as could be made today. In addition to commercial air transports, military and private aircraft must be considered in the future use of the air space. The performance of military aircraft of the future will of course greatly exceed that of transport aircraft; however for a long time to come the aviation facilities which are of concern to your group will need to consider only their cruise performance. Higher speed operations will probably be carried out in areas outside the airways and air-traffic control areas.

Some time ago the military issued invitations to bid on a new airplane. Among the performance requirements was one of special interest - the airplane had to be able to take off and land -- using plowed fields or ones covered with long grass -- within a distance of 300 feet.

Such short takeoff and landing capability is of real current interest. If all aircraft had this capability, your problem would be much easier. But, in case you consider the STOL as something brand new -- a mid-twentieth century concept -- note that the invitation to bid I mentioned was issued in February 1913 to satisfy the Army's need for a Scout airplane.

In the years since then, we have never stopped searching for ways to shorten, or eliminate, takeoff and landing runs. Until the last ten years or so, only a small effort in this direction was expended, and the advances made were applied in reducing wing area to permit still greater maximum speed. Learning how to fly fast was itself so big a job that most of our energy was concentrated upon that task. In passing I might say that this business of learning how to fly faster continues to be a very big job!

Let us look at the progress made in reducing landing and takeoff speeds. In the 'twenties, de la Cierva designed his autogiro. It was a step in the right direction, but one not far enough forward to result in the autogiro's enjoying more than a very modest success. In this period too some work was done with high-lift devices -- slots, flaps, new air-foils -- and a few airplanes were designed and built that could take off after only a very short run. But again the emphasis was so much on speed that these airplanes were considered little more than curiosities.

By the end of the 'thirties, the first real answer to the problem had been provided -- the helicopter. Vertical takeoff, with no forward run, had become possible. I need not recite the many ways in which the helicopter has since then proved its utility. The helicopter flies too slowly to suit many needs, and there seems to be little hope of increasing its speed materially. Nonetheless it is to be expected that there will be substantial further development of the helicopter, and, in fact, we at the NACA are devoting considerable effort to the study of problems peculiar to this type of aircraft.

Today, however, I would like to give primary attention to some of the other types of air vehicles that have been proposed. Users of aircraft, both military and civil, will doubtless always be like the little boy who wants to have his cake and eat it too. They want vertical-rising, or at least very short takeoff, capabilities -- plus real speed, preferably supersonic speed. Particularly in the case of the military, the need has become so great in the last few years that substantially increased effort has been directed to the solution of the many problems involved.

The solutions suggested have been many. You are doubtless familiar with the concepts: The VTO, the zero-launcher with its corollary, the air-mattress landing gear; the catapult and arresting gear, for use with land-based aircraft; the hydro-ski and the pantobase; the coleopter; the STOL -- my list is by no means complete. The combinations and permutations of the devices which offer the possibility of both short takeoff and high speed are seemingly infinite.

What I propose to do now is to discuss some of the possibilities from the point of view of the research man. At the laboratories of the NACA, we concern ourselves with the problems of aerodynamics, structures and propulsion -- to explore, to measure, to provide design information. It is not the NACA's business to attempt the design of new air vehicles or their engines, any more than it is the NACA's business to ponder such very real problems as operating costs and production feasibility. The military and the commercial operators make known their needs; the industry determines how well it can satisfy those needs, and then designs and builds the end product. We at NACA realize full well that the job is by no means done when we have completed our part of the task.

First, consider briefly the VTO concept. It is of special interest to the military because it combines the capabilities of vertical life and high speed in forward flight in a single aircraft. What makes this concept attractive now is the development of jet engines with a very high thrust-to-weight ratio. In order to fly very fast we have to provide our aircraft with very powerful engines of low weight, so powerful in fact that they could lift the aircraft straight up, as easily as they could propel it at supersonic speed.

One of the simplest types of VTO aircraft is one that stands on its tail, pointed upwards. Either turboprop or turbojet engines can be used. Because its engine provides enough thrust to overcome its weight, it can take off and climb straight up. Once in flight the VTO tips over to a horizontal position and moves forward quite fast. In landing it backs down tail first.

Unfortunately, the VTO involves problems other than sufficient thrust. How to keep the aircraft thoroughly under control during the critical periods of takeoff and landing are lumped in the deceptively uncomplicated phrase -- stability and control. At the NACA we have been studying various aspects of this very large problem for the past seven or eight years. Real progress has been made.

You are all familiar with the VTO prototypes which Convair and Lockheed have built and flown. I don't think it is any secret that other companies, Ryan for example, are active in this field, actually making hardware, to use a phrase popular in the area of development.

There are of course variants of the VTO. The coleopter -- an exotic French name for the combination of ring airfoil and ducted fan -- is one of these. Announcement has been made that Kaman has a Navy contract for a coleopter. Still another way to design a VTO is the flying platform. Charles Zimmerman, an aeronautical research scientist at our Langley Laboratory, patented the idea of having the operator of the flying platform stand on top of a ducted fan or a small rotor. What is novel about the flying platform is the simplicity of control; all the operator does is lean in the direction he wants to go. Hiller and deLackner have built flying platforms, the former for the Navy, the latter for the Army.

The zero-launcher approach places an essentially conventional airplane on the same kind of zero-launching track that would be used for a guided missile like the jet-propelled Martin Matador. What gives the zero-launched airplane the necessary kick in the pants to get it into the air is the same kind of JATO-type rocket used to start the Matador on its way. Martin has modified a Republic fighter and made zero launchings. At the end of such a flight there are at least two possibilities. If the airplane has sufficient range to get back to conventional runways, it can of course use conventional landing gear. If not, it can come down on a mattress-like affair. Similar in concept, if different in execution, is the technique of using a catapult to shorten the takeoff run of land-based planes. The landing run can also be greatly reduced by use of an arresting gear. Such devices would appear to have their ultimate application in satisfying military requirements.

Another possibility of reducing takeoff and landing runs is by use of boundary layer control. For more than a half century, since Prandtl's earliest work, boundary layer control has been in the unhappy state of being always a bridesmaid and never a bride. Everyone recognized the possibilities inherent in control of the boundary layer, but the cost in weight and complexity was so high that flaps and slots and leading edge slats -- which themselves were very helpful in achieving higher lift -- inevitably were used.

Now, it seems as if the boundary layer control may actually find favor -- and become a bride. The thinner wings we are using today, to attain higher speed, makes more difficult the job of designing aerodynamically effective flaps, and even more difficult the task of building them. The jet engine provides a ready and not too costly supply of air to draw in, or blow off, the boundary layer. Right now, the most likely use of boundary layer control is on Navy carrier-based aircraft, where reduction of stalling speed by even a few knots is very important, especially during the critical period of landing.

In the future, it may be used as a landing and takeoff aid on Air Force and commercial jet airplanes, but in such instances it is to be expected the application of boundary layer control will be more to enable new aircraft of improved performance to use existing long runways rather than to permit markedly shorter takeoffs and landings. Again, I am speaking of a concept that is not brand new. Even before the end of World War II the Germans had worked vigorously on the idea of applying boundary layer control to one of their Arado bombers. Here in the United States a number of experimental boundary-layer control installations have been made and now are receiving flight evaluation.

By its very name the convertiplane suggests the dual utility which we in America hold so dear -- with our station wagons that serve equally well as a small truck and the go-to-church car of the family. It is an aircraft that takes off like a helicopter and then after the rotor system has been transferred into a set of giant propellers flies like an airplane. Here again we have an idea that goes back a good many years as any of the several convertiplane pioneers of the greater Philadelphia area will quickly recall.

Many variants of the convertiplane idea have been suggested. Instead of just tilting the propeller-rotor system some workers in this field would tilt the entire wing. That either proposal <u>can</u> be made to work, providing sufficient development effort is invested in the project, no one doubts. Whether such a device would prove feasible for military or commercial use depends on the same considerations of production cost, operating economy, etc., which must be pondered when any of the other aircraft we have been discussing are proposed.

In the United States and elsewhere, aircraft people are also working on the problem of how to use turbojet engines in place of the propeller-rotor system of a convertiplane. In other words, install jet engines that during takeoff and landing would be pointed downward to provide vertical thrust, and then be tilted to the horizontal position to give the desired thrust in forward flight. Bell Aircraft has built a flying test bed to carry forward its work in this area. In Great Britain they have a similar project which they call a flying bedstead.

Still another way of accomplishing both vertical flight and jet-engine speed is to mount the power plants in a permanent, horizontal position and then, using vanes or other suitable devices, turn the jet blast downward or rearward. Some thirty years ago, Zahm suggested the idea of using a venetian-blind wing on an otherwise conventional propeller-driven airplane. For several years at our Langley Laboratory we have been working with small models, powered either by electrically-driven propellers or by externally-supplied compressed air jets, which demonstrate the possibility of achieving satisfactory stability and control both in forward flight and in the more critical takeoff and landing phases.

Among the most recent work at the Langley Laboratory has been a study of the aerodynamic, stability and control, and propeller characteristics of models of hypothetical four-engine, propeller-driven, vertical takeoff transport airplanes. The models have fuselage shapes similar to modern transport planes. The work was premised on the requirements that, in normal forward flight, such aircraft should be efficient and have good flying qualities. It was assumed that for such basic considerations as passenger comfort and cargo loading, the fuselage should remain essentially horizontal at all times. Both the tilting-wing and the venetian-blind wing were studied experimentally as well as theoretically. For the tilting wing, our engineers noted that "this involves some obvious mechanical complications." For the other arrangement, while it was conceded "the mechanical complications may be somewhat less severe," it was cautioned that "there are some obvious problems involved."

The layout of the hypothetical airplane was not intended necessarily to represent an optimum design, or even a design in which a VTO transport would find its greatest usefulness. It was based on the use of four Allison T-56 turboprop engines driving twenty-foot diameter propellers producing a total static thrust of 63,000 pounds. Design gross weight was 60,000 pounds with a useful load estimated at 19,000 pounds. This included forty-five passengers or 10,000 pounds of cargo, 500 pounds for crew and 8,500 pounds of fuel. Maximum still-air range, at 40,000 feet altitude -- at a speed of 460 mph -- would be about 1,500 miles. With necessary allowances for climb, let-down and fuel reserve, the commercial range would be something less than 1,200 miles.

It was calculated that a conventional airplane -- using conventional runways -- could achieve the same load, speed, and range as the VTO transport with one-half the power, and that it would weigh only seventy-five percent as much. With frank admission our people were not in a position to judge how operating costs would compare, or to assess how much the VTO and landing capability would be worth. They did conclude, however, that on the basis of the current state of the art, VTO transport airplanes which can be designed and built today could perform useful service in certain military and commercial operations. As engines of lighter weight become available and additional knowledge is acquired their performance can be substantially increased.

Similar conclusions I believe can be made respecting other suggested ways of providing both vertical rising capability and high speed. Which of the presently proposed concepts will become most successful -- or whether an entirely new idea still to be conceived will become most successful -- time alone can tell. Be that as it may, it seems most likely in the days ahead as we spurry about, that we shall have new types of aircraft at our disposal to speed us on our way.

To summarize the performance aspects of interest to you, if the air traffic control system can deal with aircraft whose speeds lie within the range zero to 800 miles per hour, it will satisfy the general needs for a long time to come.
